Grape Sustainability in South America

Present climate assessment and climate change impact evaluation

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Introduction and Objectives

Knowing the evolution of climate for next 20-50 years provides valuable information for adaptative and mitigation measures in the agricultural sector, such as the selection of the best plant variety or the best areas where the companies can invest.

Many tailored products exists aimed at estimating climate change for different variables of interest. However, many of them are not suited to the specific needs of the stakeholders. For this reason, users are often aided by purveyors of climate information.

Here, we aim to explain the sequence of steps that any tailored product should follow to be co-developed with stakeholders. As an example, the methodology was applied to four widely used wine indices in South America, but it can be easily adapted to any agro-climatic index and to any world region.

Study Area

South America was chosen as a case study of a region likely to experience significant climate impacts in the coming decades (Figure 1). It is also a highly problematic region to study, due to few meteorological observations, few regional models available, high model bias and strong local effects.

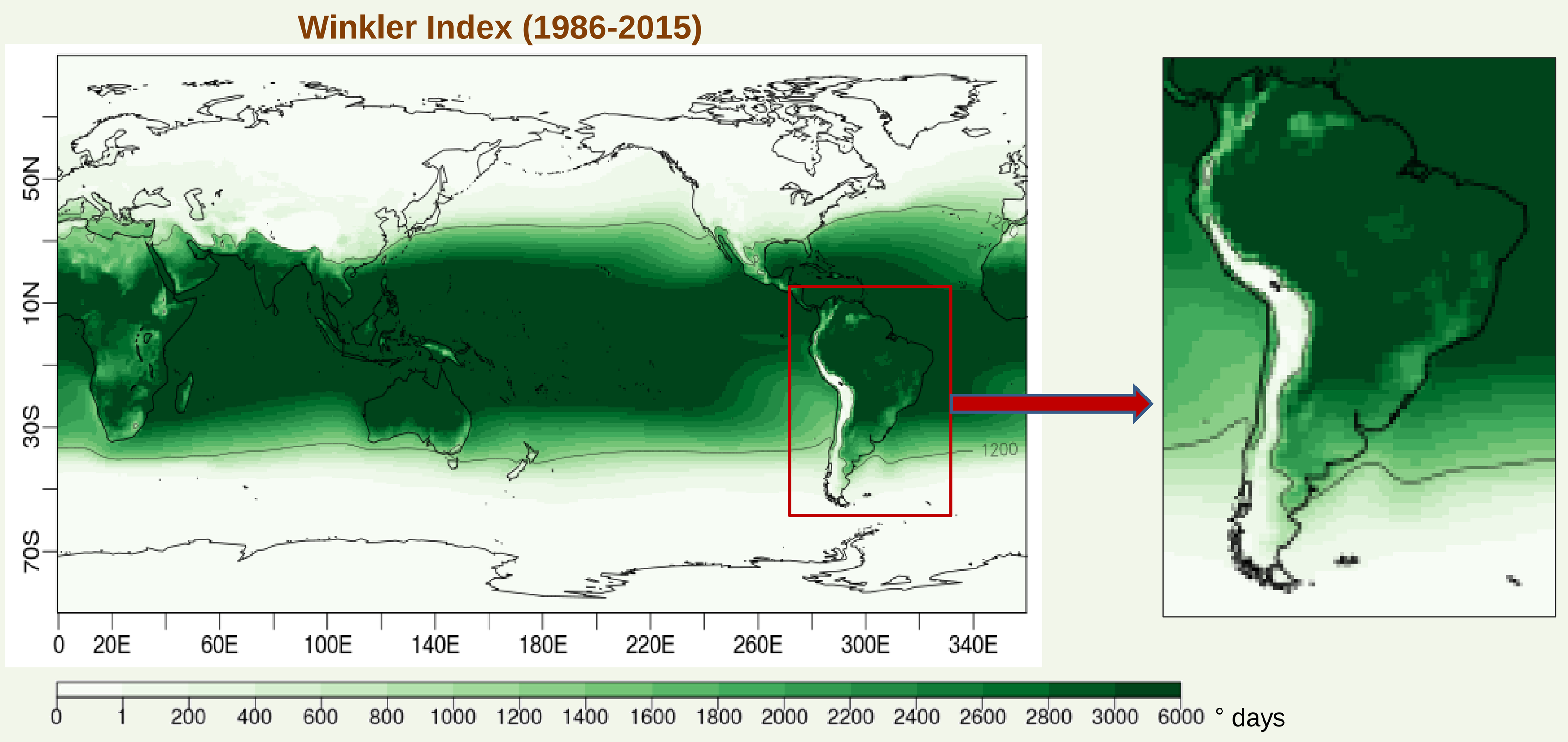

Figure 1. Study area. Green color represents the average values of the Winkler Index adapted to the Southern Hemisphere and measured for present climate (1986-2015).

Data and Methodology

The more advanced tailored tools allow a robust estimation of the projected climate change for any agro-climatic index. They follow a ***probabilistic approach***, being based on multi-model ensemble of the highest possible number of state-of-the-art climate models. The main advantages of this approach are the ***reduced model bias*** and the possibility to estimate also the ***uncertainty*** associated to each agro-climatic index thanks to the high number of model simulations.

In this example, two emission scenarios RCP 2.6 (low future greenhouse emissions) and RCP 8.5 (high emissions) were employed, for a total of 21 simulations from 9 different models with a spatial resolution of ~100-200 km , but a higher number is suggested. All of them are GCMs proceeding from the CMIP5 project.

Co-design of Wine Indices

In this study, four wine indices were defined in the co-design phase with the stakeholders (a wine company). Their main difference with the standard wine indices is that their definition is adapted to the Southern Hemisphere, where the warmest months are from October to April:

- The **Winter Severity Index** is the mean temperature of the coldest month (July in the Southern Hemisphere).
- The **Winkler Index** is the cumulated sum from October to April of all the degrees of daily mean temperature above 10°C.
- The **Mean Temperature during the vegetative period** is the average mean temperature from October to April.
- The **Total Rainfall during the vegetative period** is the total precipitation amount from October to April.

The selection is conditioned on the availability of climate models and observations in the study area. For example, in South America there are few observational datasets and few regional models available. In this cases, it is preferable to employ daily reanalysis datasets and global climate models instead (in this study, respectively the ERA-Interim and the CMIP5 models).

Multi-model Ensemble

- The purveyors of climate information measure the average vales of the agro-climate indices of interest during present climate, for example during last 30 years (see Figure 2) and compare them with the same values estimated from the hindcasts (past simulations) of the climate models they utilize to build the multi-member, multi-model ensemble (interpolating them to the same spatial resolution of the observations, if necessary), typically by means of a ***Taylor diagram*** of the average values of each variable used to define the agro-climatic indices (Figure 3).
- For each variable, simulations with low skill in the Taylor diagram are discarded following an objective criteria (in this study, variance ratio > 0.6) and a new multi-model ensemble is generated without the less-performant simulations. Often a weighted multi-model is generated, to give more weight to better simulations.
- Finally, for each emission scenario, the mean climate change associated to any agro-climate index is estimated as the difference between its projected future average value (2031-2060) in the new multi-model ensemble and its historical average value (1986-2015) in the same multi-model (Figure 3). In this way, model bias are minimized.

Wine Indices

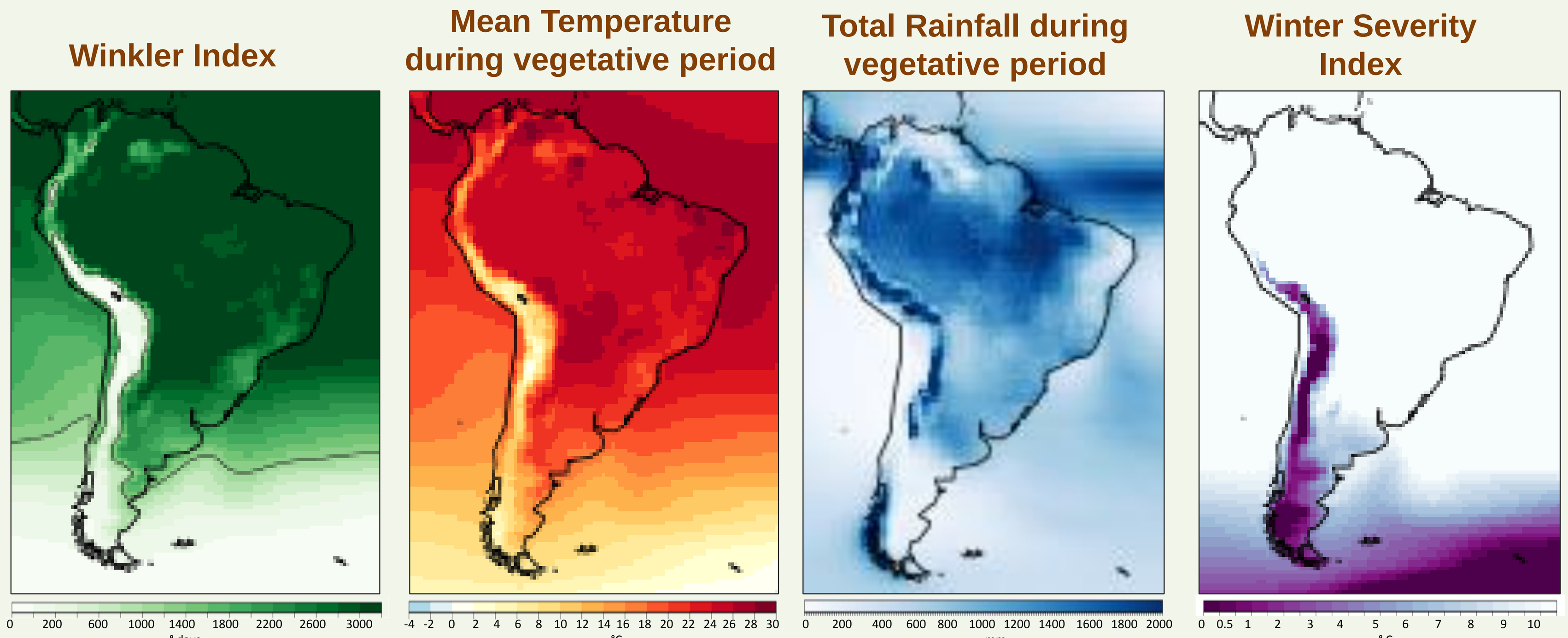

Figure 2. Average observed values during present climate (1986-2015) of the four selected wind indices. Source: ERA-Interim.

Taylor Diagram

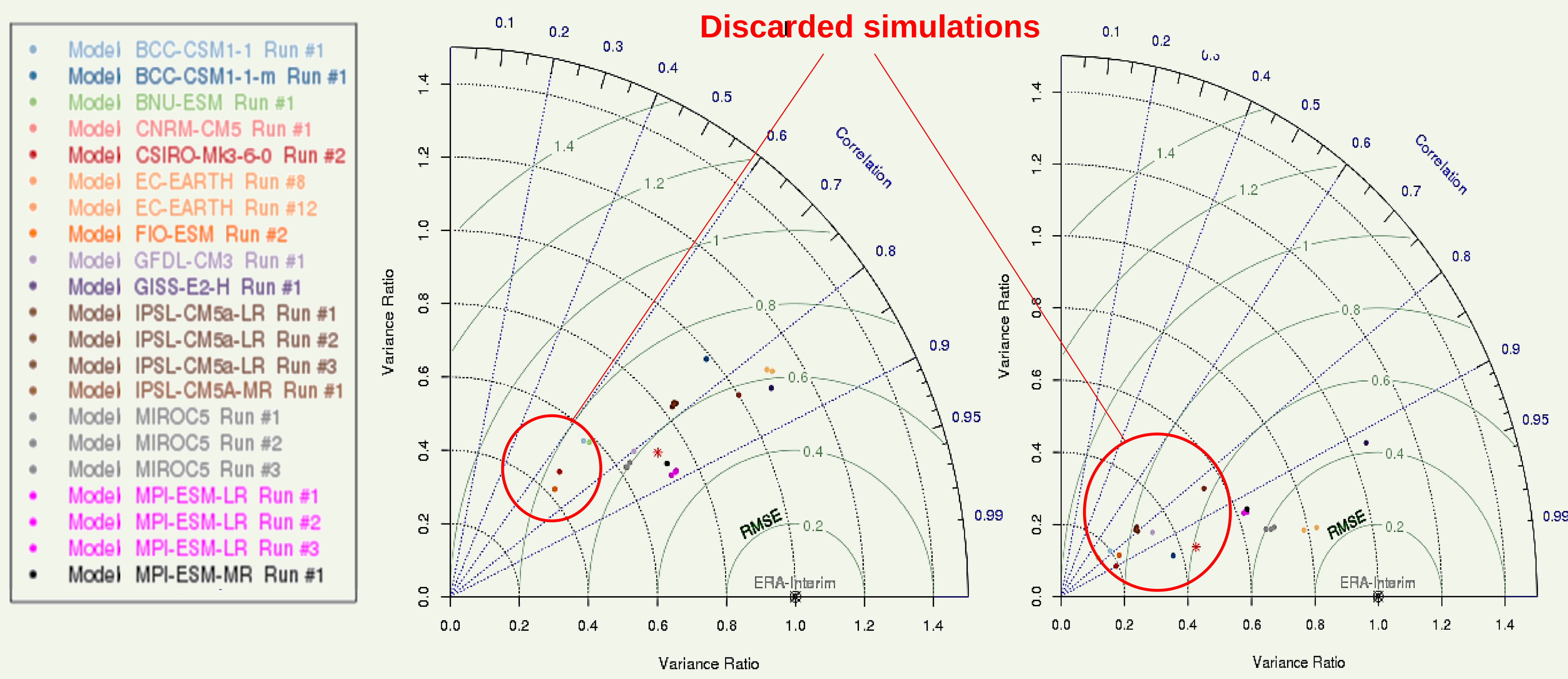

Figure 3. Taylor diagrams for yearly temperature (*left*) and precipitation (*right*): each point represents a model simulation (also called *run* in the legend), X and Y axis show the ratio between its simulated and observed variance, while the blue numbers on the outer semi circumference show the correlation between the simulated yearly variable and the observed one. Green numbers in the inner circles show the Root Mean Square Error (RMSE) of the simulated variable.

Results

The main results of this study is the evaluation of the mean climate change for period 2013-2061, with respect to period 1986-2015, for the four selected wine indices and the two emission scenarios (Figure 4):

- The Winkler Index is projected to increase considerably over all South America, especially for the more extreme scenario RCP8.5 .
- Mean Temperature increases all over the study area, with a spatial pattern similar to that of the Winkler Index, except for the areas with high elevation, where the Winkler Index can't increase because mean vegetative temperatures are below 10 °C.
- Total Precipitation increases only slightly in the eastern part of South America and in the northern part of the Andes for both scenarios and decreases slightly in the south-western part.
- The Winter Severity Index increases all over the central and northern part of South America.

These changes will allow grape to grow also in areas which nowadays are too cold, too wet or too dry.

Discussion and Conclusions

An overview of the methodology for co-developing tailored products with stakeholders was explained and applied to a set of four wine indices in South America.

Results of this study suggest that many areas in South America are very likely to experience better conditions for grape production in next 20-40 years. However, analysis at local sites (instead of grid points) is often problematic due to the influence of local effects (mainly orography and vegetation), of the low resolution of models and of the lack of observed data in many areas, which impede the downscaling of the indices at local sites. In this cases, for certain variables it is still possible to apply simple bias corrections to remove some local effects, like the mean temperature bias due to elevation.

In summary, it's critical for stakeholders and purveyors of climate information to co-design together both the best set of indices needed and the best layout of the product outputs. State-of-the-art tailored products should present the results summarizing all information in a few graphs and tables easy to understand. In the final co-design step, visualization with GIS software is commonly employed for its high degree of customization to satisfy the needs of the stakeholders.

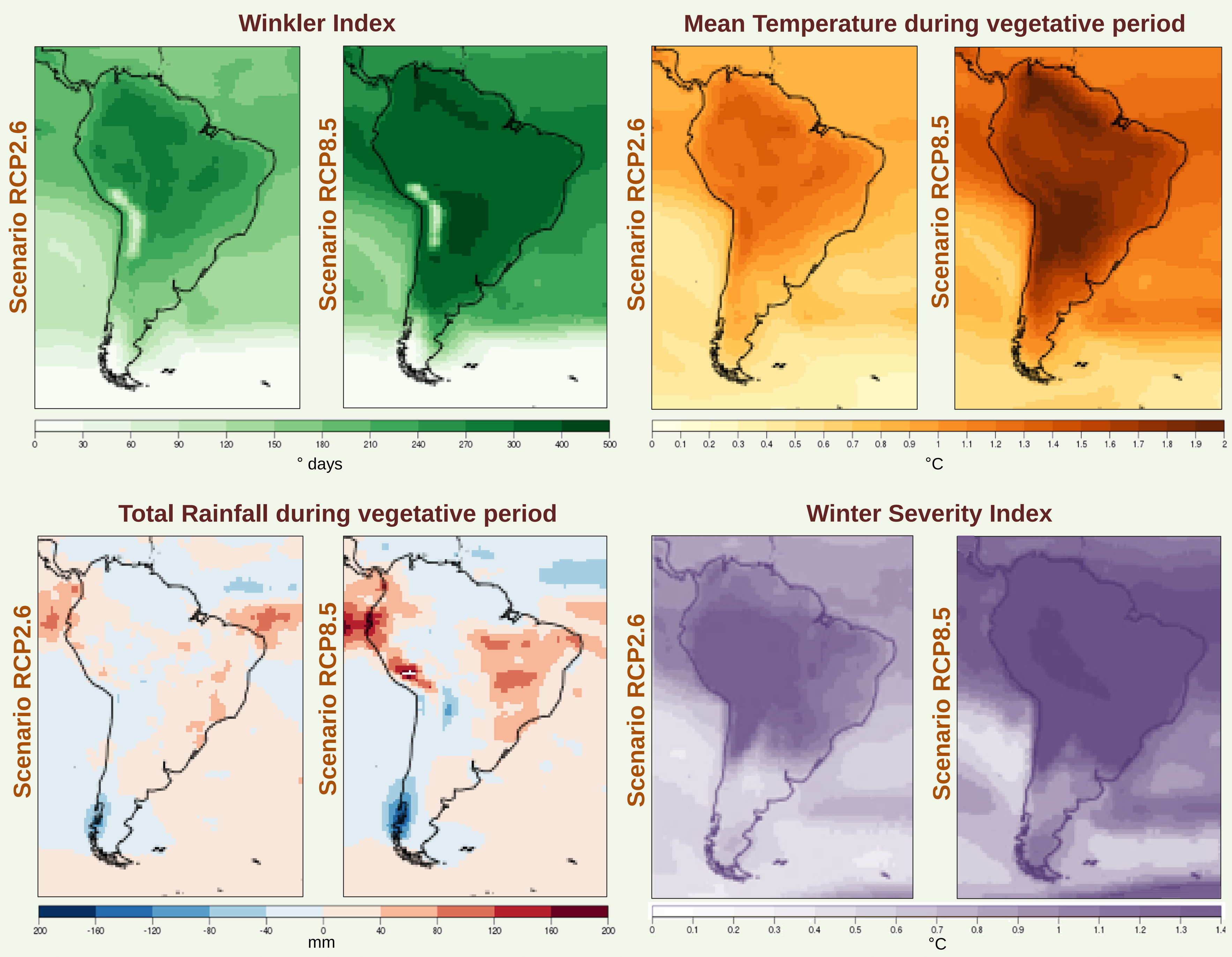

Figure 4. Mean estimated climate change for period 2031-2060, compared to the 1986-2015, for the four wine indices and the two mission scenario RCP2.6 (left image of each pair) and RCP8.5 (right image).